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Development of a Taxonomy of Human Performance:

A Review of the Third Year's Progress

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Technical Progress Report 3

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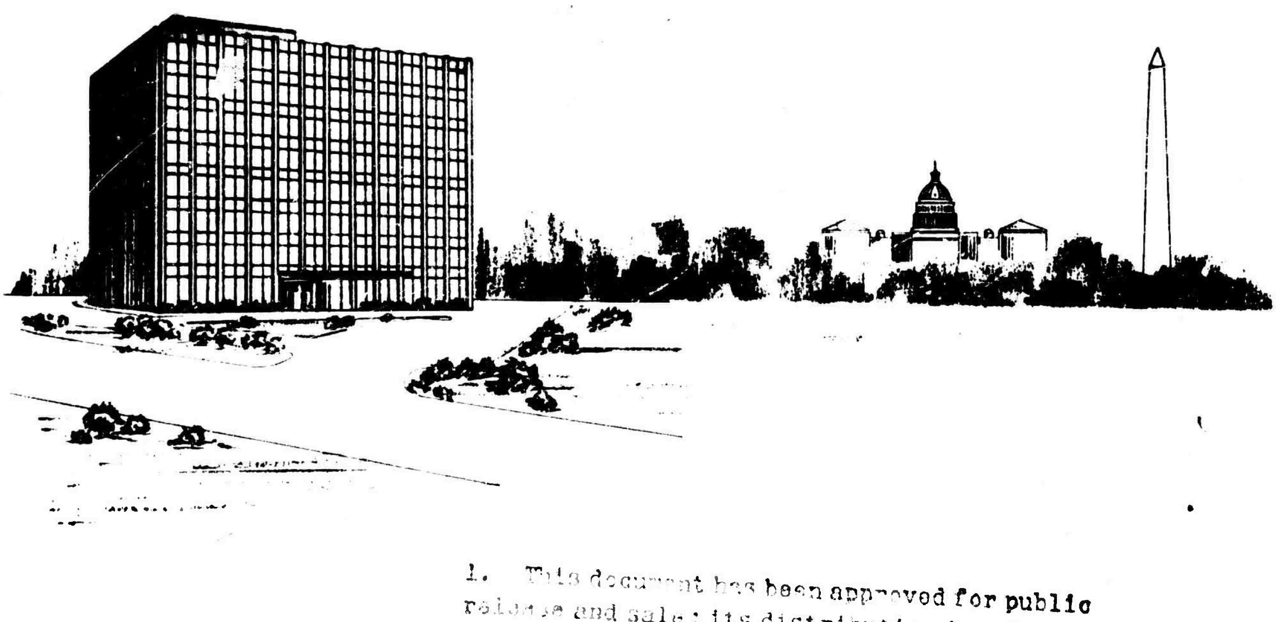

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DEVELOPMENT OF A TAXONOMY OF HUMAN PERFORMANCE:

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Edwin A. Fleishman

Robert W. Stephenson

TECHNICAL PROGRESS REPORT 3

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ABSTRACT

The purpose of the AIR taxonomy project is to develop and evaluate systems for describing and classifying tasks which can improve generalization of research results about human performance and to develop a common language for communicating between researchers and individuals who need to apply research to personnel problems. During two previous project years, three different taxonomic systems were developed, each of which seemed to have maximum relevance for a different type of application: the ability-requirement approach; the task characteristics approach; and a third approach based on information-theory.

During the third project year, two of the three provisional approaches were subjected to user-oriented evaluations. The ability-requirement and task characteristics approaches were used to post-dict mean values of performance measures and relevant factor loadings for a variety of tasks. Work was also initiated on the design of binary decision flow diagrams of the type that will simplify decisions about ability requirements so that decisions can be made by relatively untrained personnel. The information-theory approach was revised and reformulated as a more general systems-language approach; a specially designed experimental apparatus was built for its evaluation. Also, as a separate effort, a new "information processing" systems language was developed which seemed to be more readily adaptable to the description of complex tasks. Finally some evaluation was made of a criterion measure classification scheme.

Progress was made toward the development of computer-compatible information retrieval procedures developed to allow interested users to retrieve data according to the task descriptive system of interest. These procedures were applied to several portions of the Human Performance Data Base, previously assembled, with promising results.

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INTRODUCTION

The project initially was a response to the frequently stated needs from those concerned with personnel selection, training, and the design and use of equipment and systems which involve human factors. One military psychologist stated the problem as follows:

> "In recent years, human factors analysts and training psychologists have called for a taxonomy of tasks to provide a breakthrough in the state-of-the-art. The reasoning behind this is as follows. Currently, techniques of task analysis require that every task performed in a system or job be treated as a unique entity or aspect of the work. For example, two tasks that are identical in terms of the kind of work performed may still differ in the kind of equipment involved, environmental factors affecting the task . . . operational conditions, and a multitude of other factors. Thus, the "alignment of a transceiver" can differ considerably from one type or model of transceiver to another . . . from one electronics technician to another, etc. As a result, task analysis of even one job or man-machine system can involve the study of an enormous number of tasks and their elements." (Silverman, 1967).

Similar points have been made by Altman (1964), Bloom (1956), Cattell (1963), Cotterman (1959), Eckstrand (1964), Fitts (1962), Fleishman (1962, 1967b), Ginsberg, McCuller, Meryman, Thomson and Witte (1966), Hackman (1967), Haggard (1964), Melton and Briggs (1960), Miller (1956), Sells (1963), and Stolurow (1964).

One consequence of the problem is the difficulty of applying previous research results since there is a lack of dependable methods for determining how similar two tasks really are.

> ". . . as new systems are conceived for the exploration of space, for defense, for command and control, it appears that much of the accumulated data and experience of the past are largely inapplicable and that the problems of skill identification, training, and performance must be restudied almost from scratch. Why is this the case? Why such a waste of prior findings?" (Fleishman, 1967a).

There is an additional complication associated with possible solutions to this problem. The determination of the similarity of tasks could impose special task-description requirements on those who conduct human performance research, and procedures for describing tasks in a standardized way may need to be provided.

Project Objectives

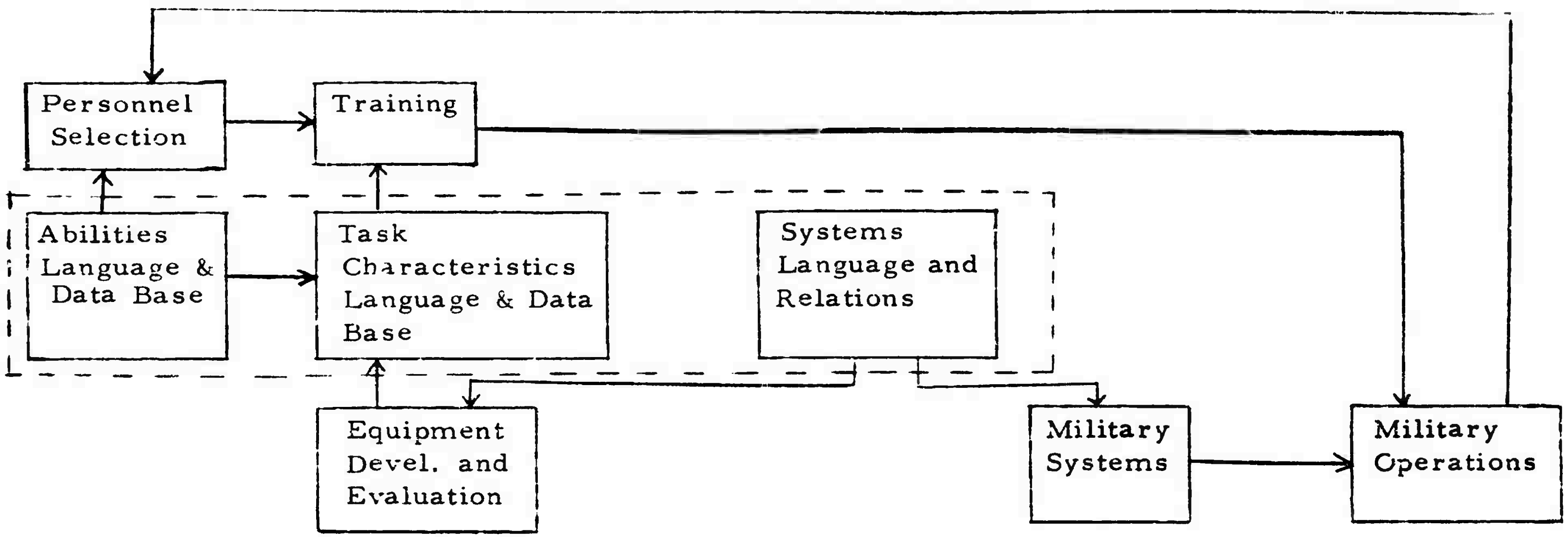
The AIR taxonomy project was initiated in September 1967 (under a contract with the Advanced Research Projects Agency) as a response to the many expressions of concern about the need for work in this area. Specifically, our objectives were to develop and evaluate systems for describing tasks which could improve generalization of research results about human performance and to develop a common language for communicating between researchers and decision-makers, which would help organize human performance information for maximum use in training, design, etc.

This general objective remained for the first three years, but our approach to the problem changed slightly during the project. During the first year, we were looking for <u>the</u> taxonomy, i.e., a general taxonomy of human task performance which could be applied to different subject matter areas (e.g., the effects of conditions of learning, noise, etc.) and different types of applied decisions (selection, training, human engineering). The project developed several approaches to this general type of taxonomy. Briefly, these were the ability-requirement approach; the task characteristics approach; and several systems language approaches. Some work was carried out utilizing a more comprehensive and eclectic "man for all systems" approach, which focused on classifying tasks in terms of information retrieval requirements (Chambers, 1969). More recently some evaluation was made of a general task classification system confined to type of criterion performance measured (Teichner and Fleishman, 1971).

It should be apparent that the various approaches rely on differences in conceptualization and research strategy. Some approaches are essentially empirically inductive, others involve testing of a-priori theoretical formulations. The arguments for and against these various approaches, our initial literature integrations and consultations, and our preliminary conceptual development gradually began to convince us that more than one provisional approach was needed. Consequently, three different provisional approaches were decided upon, each of which seemed to be most relevant for a particular set of operational decisions: the ability requirement approach; the task characteristics approach; and the systems language approach. The decision to set up more than one system may now appear obvious, but having said it, we regard it an insight which provided us with a major advance towards the solution of taxonomic problems. We also think that the three approaches we selected provided fairly good coverage of personnel decision problem areas.

Figure 1 provides an overly simplified schematic of military system components and their relationships to the three performance descriptive languages which we selected.

The abilities language is most relevant for selection decisions. The personnel specialist develops his primary personnel criteria from an analysis of job operations in all of their complexities and attempts from this to establish the characteristics of personnel which are needed to meet these criteria. For this selection decision he must know the individual differences in human abilities which underlie task performance and have an appropriate data base from which to construct selection criteria. However, it was felt that these ability categories, since they are derived from the empirically established intercorrelation among task performances, would also be useful in organizing information about tasks used in other areas of human performance (e.g., the effects of noise, drugs, training methods, etc.).



- - - - - - Denotes the objectives of the project

Figure 1. Role of Taxonomic Language Systems and Data Bases in Military Functions

The task characteristics language appears most relevant for training decisions. The training specialist requires information about the interaction between personnel characteristics, properties and requirements of the task independent of the person, and the expected operating conditions. For these training decisions tasks must be defined in terms of task characteristics. As before, the applicable data must be collected but in a form or language relevant to his purposes. It is very important to note that the abilities and the task characteristics languages draw data from the same source, i.e., descriptions of human task requirements. To a considerable degree they represent the same information expressed in different languages.

The systems language is most relevant for human engineering decisions, but it is also a language of more general utility. Specialists concerned with hardware have to assume the availability of appropriately selected and trained operators. Their requirement is not for a unique, human performance language and data base, but for the translation of human performance information from such a language to a language in which systems are described. In the same sense that one cannot add apples and oranges, the man-machine system specialist must express human data and machine data in the same units. Perhaps the most widely used systems language which can accomplish this is that of information theory. The terms and the relationships among terms within this statistical language are known or can be determined and are already in use by the systems engineer. The requirement then is that of developing the means for translating information from the task characteristics and ability requirement languages to the system language, and of determining which terms and relationships in the systems language are implicated and which are not.

Overall Project Plan

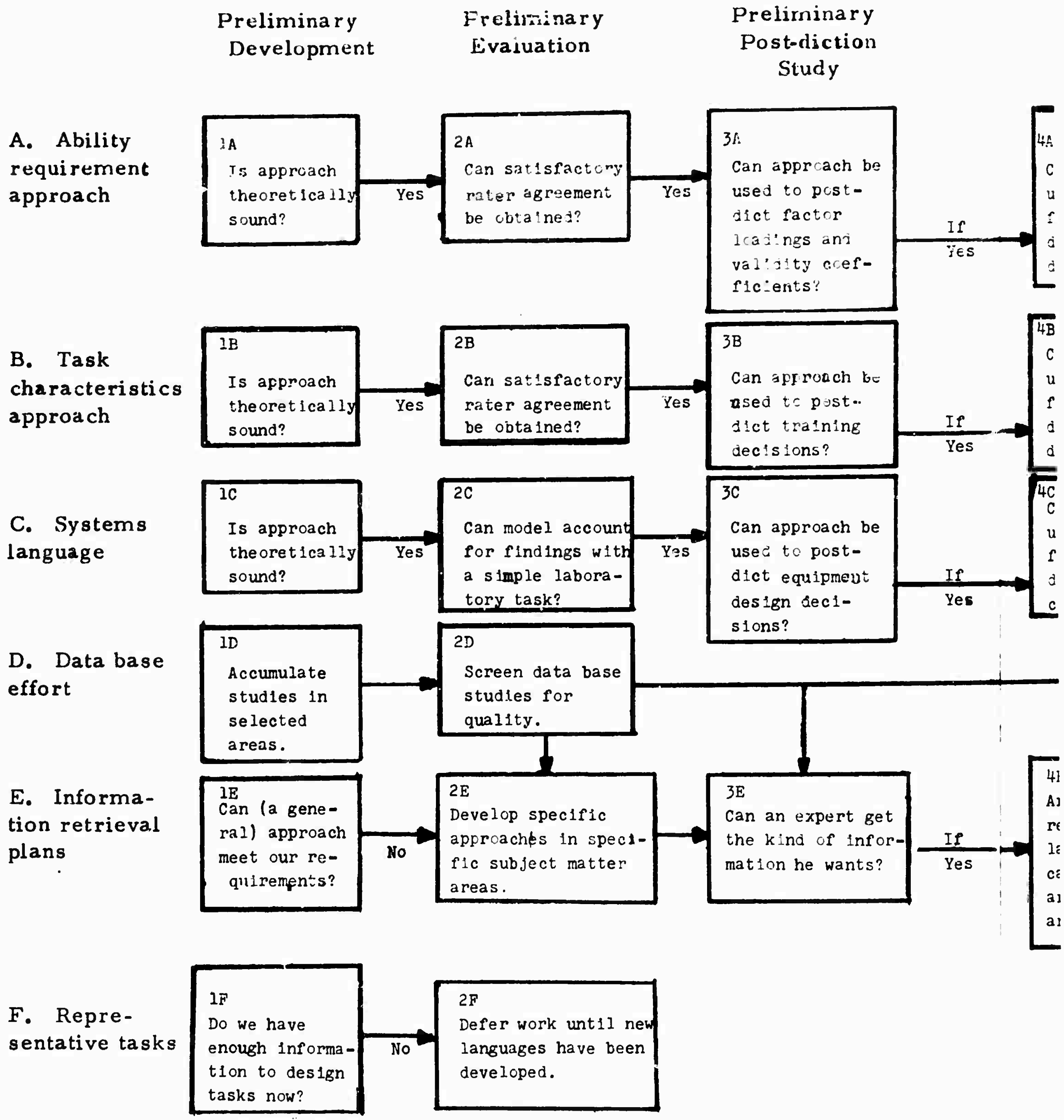
The overall plan for the project is illustrated in Figure 2. Each box

may be considered to be a decision checkpoint which could result in dropping a provisional approach if the answer were to be negative. We will discuss each row of this diagram in detail.

Ability-requirement approach. The ability-requirement approach (See Row A of Figure 2) describes a task in terms of the abilities required to perform it. These abilities are inferred from the intercorrelations among performances on selected groups of tasks. The major source of information about abilities comes from the factor analysis literature. However, prior to this project, little had been done to indicate how well these ability descriptors could actually be used by observers to describe tasks.

The ability-requirement approach (as suggested in Figure 1), was expected to be most relevant for applied decisions about the selection and classification of personnel. Given, for example, two tasks that are similar in the sense that the same pattern of abilities is required, one would expect the same battery of selection tests to be useful in both cases. The applied relevance of this approach is not restricted to selection problems, however, since one would also expect the same kind of training programs to be useful in two tasks with similar ability requirements, even if the specific characteristics of the practice situation were to change somewhat. Similarly, the effects of various environmental stressors (e.g., noise) might show consistent variations for tasks with similar sets of abilities required for task performance. No one had previously tested this possibility.

Task characteristics approach. This approach (Row B of Figure 2) called for the description of tasks without reference to either the person or the environment, i.e., the objective was to find a way of classifying tasks which was restricted to task characteristics alone, and would consequently be independent of the characteristics of the organism as well as the environment.


Preliminary Development
Preliminary Evaluation
Preliminary Post-diction Study
A. Ability requirement approach
1A Is approach theoretically sound?
Yes
2A Can satisfactory rater agreement be obtained?
Yes
3A Can approach be used to post-dict factor loadings and validity coefficients?
If Yes
4A
B. Task characteristics approach
1B Is approach theoretically sound?
Yes
2B Can satisfactory rater agreement be obtained?
Yes
3B Can approach be used to post-dict training decisions?
If Yes
4B
C. Systems language
1C Is approach theoretically sound?
Yes
2C Can model account for findings with a simple laboratory task?
Yes
3C Can approach be used to post-dict equipment design decisions?
If Yes
4C
D. Data base effort
1D Accumulate studies in selected areas.
2D Screen data base studies for quality.
E. Information retrieval plans
1E Can (a general) approach meet our requirements?
No
2E Develop specific approaches in specific subject matter areas.
3E Can an expert get the kind of information he wants?
If Yes
F. Representative tasks
1F Do we have enough information to design tasks now?
No
2F Defer work until new languages have been developed.

A

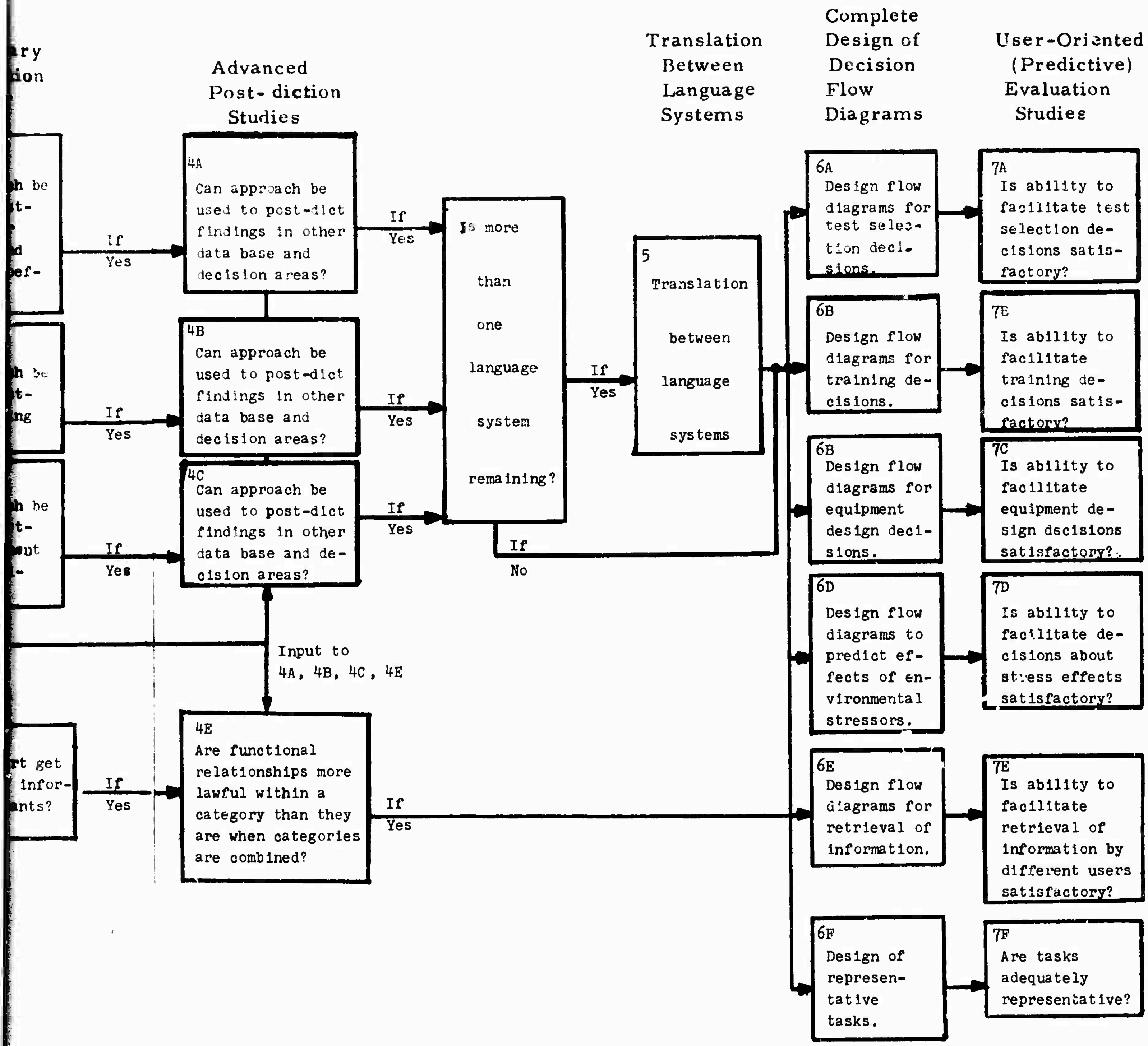


Figure 2

Decision checkpoints to determine allocation of taxonomy project resources

B

The task characteristics approach was designed late during the first year of the project. Twenty-five task characteristic rating scales were developed, concerned with such things as the goal of the task (e.g., difficulty of goal attainment), the response (e.g., degree of response chaining), the procedures (e.g., number of steps), the stimulus (e.g., regularity of stimulus occurrence), and stimulus-response relationships (e.g., reaction time). These rating scales were revised several times during the second year of the project, and subjected to rater agreement studies during the third year.

Systems language approach. The systems language approach (Row C of Figure 2) differs from the other provisional approaches in that it is based on a general model which starts with a set of definitions, relationships, and classes and has meaning in the same sense that a mathematical or logical system has meaning. In this sense, the system is complete before any attempt is made to apply it to observations, and it is not subject to inventive revisions in quite the same way as the other approaches.

The systems language approach defines a task as an information transfer between a source and receiver in a system. All tasks are characterized as imposing constraints which are visualized as restrictions placed upon the random sampling of stimulus and response events. These constraints define a task as a unique situation. The constraints may be restrictions on how events are sampled or restrictions on which particular events are sampled. These constraints introduce redundancy into the information contained in the stimulus and response sets. We postulate that tasks can be classified in terms of the effects of increasing amounts of redundancy upon information transmission between the source and receiver.

The systems language is eventually designed to encompass the other two provisional approaches. This will require a translation between the three language systems. Potentially, this system language can be developed to the point where it will be useful for any one of a variety of

applied decisions (e.g., selection _or_ training _or_ equipment design), rather than being primarily useful for one or two types of applied decisions, as seems to be the case with the other two provisional approaches. Until this capability is demonstrated, however, we justify the inclusion of the systems language approach on the grounds that it seems to have more utility for equipment design decisions than do the other two provisional approaches we selected.

Data base effort. The data base effort (Row D of Figure 2) was initiated early during the first year as an important part of our plans for evaluating the various provisional approaches. Each provisional approach was to be evaluated in terms of its ability to post-dict findings in the one decision-making area which seemed most relevant for that approach (See Column 3 of Figure 2), as well as in terms of other data base and decision areas which had not been used in the development of that approach (See Column 4 of Figure 2). The basic rationale here was that data already published in various substantive areas provide a way of testing the utility of task classification systems. The approach was to classify the tasks within an area and to examine the experimental data in terms of consistencies within task categories. If the tasks used in these studies are classified in terms of a given performance system, do we improve the kinds of generalizations it is possible to make?

The following areas were selected initially:

Environmental areas

- Auditory noise
- Atmospheric thermal environment

Training areas

- Knowledge of results (feedback)
- Massed versus distributed practice

Psychophysiological areas

- Psychoactive drugs

Approximately 600 studies were collected which met our two selection criteria: (1) being based on experimental data and (2) containing a detailed description of the tasks. These studies were assembled as a continuing effort during the first three years of the project, and used for evaluation studies of various kinds during the second and third years. Particular attention was given to one Environmental Area (noise) and one Training Area (massed versus distributed practice).

Information retrieval systems. Our work on information retrieval systems (Row E of Figure 2) followed the same pattern as the rest of the project. We started out with plans for a general "man for all systems" information retrieval model, and gradually changed in favor of specific information retrieval plans in specific subject matter areas. The basic approach was to index articles in order to extract a maximum of information regarding task descriptors, subjects, experimental results, etc.

The problem with a general information retrieval model was that it was too general and too complicated. Specific models, in contrast, could be designed to answer a specific set of questions which people wanted to have answered.

The information retrieval system we finally settled upon had the following characteristics: (1) the whole article is used rather than abstracts; (2) the data base is capable of plotting functional relationships of interest to the user; (3) specific dependent variables are focused upon in order to make it possible to plot these functional relationships; (4) the data base studies are screened for quality and adequacy of description by an experienced professional; (5) the system is an open-end file, with the capability to incorporate new findings without major revisions; and (6) a separate file of selected illustrations and tables is established by copying the selected displays and providing reference information as part of the computer printout.

Representative tasks. The design of representative tasks (Row F of Figure 2) was a long-range objective of the project. The goal here was to provide laboratory tasks representative of different taxonomic human performance categories to serve as a basis for (a) task standardization and (b) further experimental work evaluating the utility of the taxonomy for generalizing experimental results on factors affecting human performance. It became apparent that much more work on the systems needed to be done before this could be undertaken. During the second year of the project, ARPA felt that within budget constraints this aspect of the project should be curtailed in favor of the data base efforts.

Although these representative tasks were expected to be an important by-product, no actual work could be initiated. Our hope was that we would, at least, be able to provide a set of task specifications at a later stage of the project. Actually, the taxonomic categories and their definitions as evolved on the project do provide considerable guidelines.

The First Year of the Project

The first year of the project is described in detail in Technical Progress Report No. 1.

Fleishman, E.A., Kinkade, R.G., & Chambers, A.N. Development of a Taxonomy of Human Performance: A Review of the First Year's Progress. Technical Progress Report No. 1 Washington, D.C.: American Institutes for Research, November 1968.

During this period, the taxonomy project staff conducted three literature reviews, developed two of the three provisional approaches (Rows A and B of Figure 2), initiated work on the collection of information about a data base (Row D), and developed information retrieval plans (Row E).

The Second Year of the Project

The second year of the project is described in detail in Technical Progress Report No. 2.

Fleishman, E. A., Teichner, W., & Stephenson, R. W. Development of a Taxonomy of Human Performance: A Review of the Second Year's Progress. Technical Progress Report No. 2. Washington, D. C.: American Institutes for Research, January 1970.

During this period, the taxonomy project staff published two of our three literature reviews, developed a third provisional approach (Row C of Figure 2), conducted preliminary evaluations of the first two provisional approaches (Rows A and B), developed procedures for a "quality filter" to screen articles for the data base materials, screened the data base for quality (Row D), and made plans for a variety of post-diction studies (Column C of Figure 2).

The technical reports published during this period include:

Wheaton, G. R. Development of a Taxonomy of Human Performance: A Review of Classification Systems. Technical Report No. 1 Washington, D. C.: American Institutes for Research, December 1968.

Farina, A. J., Jr. Development of a Taxonomy of Human Performance: A Review of Descriptive Schemes for Human Task Behavior. Technical Report No. 2, Washington, D. C.: American Institutes for Research, February 1969.

Chambers, A. N. Development of a Taxonomy of Human Performance: A Heuristic Model for the Development of a Classification System. Technical Report No. 4, Washington, D. C.: American Institutes for Research, March 1969.

THIRD YEAR ACTIVITIES

During the third year of the project, the taxonomy project staff published two technical reports and presented a number of papers. The technical reports were:

Theologus, G. C. Development of a Taxonomy of Human Performance: A Review of Biological Taxonomy and Classification. Technical Report No. 3, Washington, D. C.: American Institutes for Research, December 1969.

Theologus, G. C., Romashko, T., & Fleishman, E. A. Development of a Taxonomy of Human Performance: Feasibility Study of Ability Dimensions for Classifying Tasks. Technical Report No. 5, Washington, D.C.: American Institutes for Research, January 1970.

The papers (presented at the annual meeting of the American Psychological Association, September 1969) were:

Theologus, G. C., Fleishman, E. A., & Romashko, Tania. Classification in terms of human abilities.

Farina, A. J., Jr. & Wheaton, G. R. Classification in terms of task characteristics.

Teichner, W. H. An information-theoretic approach to task classification.

Korotkin, A. L. & Chambers, A. N. A human performance data base for evaluation of taxonomies.

Copies of these papers were included in the Second Annual Technical Progress Report (Fleishman, Teichner, and Stephenson, 1970).

The project staff also made considerable progress in each of the five active areas of investigation (Rows A - E of Figure 2).

Ability-Requirement Approach

After several revisions, based on experimental tryouts, the ability-requirement scales (see Appendix A) reached adequate reliabilities for use by a small enough number of observers (Theologus, Romashko, and Fleishman, 1970). A product of this work was a reference manual called The Task Assessment Scales, for use by raters in describing ability requirements of tasks. It was decided to make a preliminary test of the post-dictive validity of these scales during the third year. This was to be done in terms of the ability of the scales to post-dict mean performance on selected tasks. Various alternative studies were considered for this purpose. The final decision was to regress judges' ratings of tasks on the ability scales towards mean performance on those tasks. It was further decided that in the same research an attempt would be made to determine whether the judges' ratings of the tasks using these scales bore any relationship to the factor loadings of the tasks obtained independently in earlier work. Despite the considerable literature on factor analysis, no previous evaluation of this type had ever been made.

To accomplish this, two different factor analytic studies were used. Judges rated each task using the thirty-seven ability-requirement rating scales. An average rating was determined so that each task could be said to have a single value on each rating scale. The ability-requirement ratings were then studied to see if they could post-dict the nature of the mean performance score for that task (e.g., number of repetitive cycles per unit time), and whether a task which was rated high in a particular ability did, in fact, have a high factor loading in that ability.

In the preliminary work using this approach, significant relations were found between the ability ratings and factor loadings. However, the ability-requirement rating scales seemed to have a problem of false positives, i.e., some tasks were rated high in terms of an ability-requirement which did not, in fact, have a significant factor loading with respect to that ability. Ways of coping with this problem were explored.

The results of these post-diction studies will be reported in:

Theologus, G.C. & Fleishman, E.A. Development of a Taxonomy of Human Performance: Validation Study of Ability Scales for Classifying Human Tasks. Technical Report No. 10.

Task Characteristics Approach

Since the initial rating scales seemed to need some improvement with respect to rater agreement, a second manual called the Task Characteristics Rating Scales was revised twice during the third year of the project, and two additional rater agreement studies were conducted. In the first rater agreement study, three research personnel were trained to use the rating scales. They then provided ratings for thirty-seven tasks. In the second rater agreement study, twenty-eight subjects rated twenty tasks (see Appendix B).

The results of these two rater agreement studies will be reported in:

Farina, A.J., Jr. & Wheaton, G.R. Development of a Taxonomy of Human Performance: The Task Characteristics Approach to Performance Prediction. Technical Report No. 7.

Work was also carried out evaluating the task characteristics approach in predicting performance on actual military job tasks. Specifically, it was possible to utilize a variety of tracking tasks, involved in another related project, in which per cent time on target was used as a criterion measure. With the aid of some additional rating scales or indices (which were tailored to the situation being investigated), it was possible to post-dict per cent time on target with a small number of these task description rating scales (e.g., number of procedural steps, precision of responses, number of responses, and number of output units).

Systems Language Approaches

The "systems language" approach did not take its current form until

very late in the second year of the project. (Previous reports refer to it as the "information-theoretic" approach; see Teichner 1970). During the third year, the plans grew clearer as we worked out the theoretical relationships to other language systems (see Appendix C). After this theoretical clarification, plans were prepared for an experimental evaluation of the model upon which the systems language was to be based. Specific procedures were outlined for three experiments and their associated computer simulations. A versatile apparatus (called the Sequential Information Processing Programmer) was developed to test the basic assumptions of the model. Briefly, this device allows for the generation of several kinds of tasks such as pattern identification, stimulus detection, recognition and classification. The system permits automatic inputing of sequential/simultaneous visual signals in an 8 x 8 array of lights and automatic recording of responses in a compatible array of buttons. Redundancy can be manipulated on both the input and output sides, as can S-R compatibility.

The actual experimental work did not begin during the third year, partially because of equipment construction delays, and partially because the project objectives were undergoing reconsideration at the time when work was scheduled to begin.

The theoretical formulation of this approach and the plans for future research will be reported in:

Levine, J. M., & Teichner, W. Development of a Taxonomy of Human Performance: An Information-Theoretic Approach. Technical Report No. 9.

A second type of systems language was developed by Miller in connection with a "user-oriented" evaluative system. Briefly, Miller's systems language is an elaboration of his earlier functional approach to classification (Miller, 1962). The approach assumes that the human is an information processor. He can code one class of information into

other classes of information where the second class is symbolic of the first. Symbols, when communicated from one individual or device to another take the form of "messages." Humans, capable of symbolic behavior, are "message processors." Four key terms found useful in developing the taxonomy were: input reception; memory; processing; and output effectors.

Within this general theoretical framework, Miller has developed a standardized set of terms for use in analyzing information system activities. A simplified description of these terms is shown in Appendix D. More detailed information about this new language is provided in:

Miller, R. B. Development of a Taxonomy of Human Performance: Design of a Systems Task Vocabulary. Technical Report No. 11.

Data Base Effort

During the third year of the project, several sub-areas in the Human Performance Data Base were classified in terms of a "criterion measure classification scheme." This system (Teichner and Olson, 1969) uses a few very broad categories of human performance which are largely determined by the nature of the criterion measures (Appendix E). The first set of decisions in this categorization involved the categories of tracking, switching, searching, and coding. Later categorizations involved the rate and complexity of inputs and outputs. The advantages of using this system as a first run at testing out the feasibility of the data base effort were (a) the relatively few broad categories involved in this system; (b) the categories involved are defined operationally by the type of measure, thus minimizing rater judgment.

Relationships between selected predictor-criterion values were plotted within (and between) these criterion-measure categories for two areas of human performance: the effects of massed-distributed learning procedure,

and the effects of noise. The results were encouraging in showing that the task categorization used seemed to help predict within each category better than was the case for combined categories. Furthermore, within certain categories it was possible to plot functional relationships which held independent of the specific task (e.g., relation of interval between practice sessions and performance). This criterion-measure classification scheme could conceivably become an important part of a data retrieval system for the three selected provisional approaches referred to earlier. This phase of the work helped us work out many methodological problems, such as equating dependent measures across tasks and developing ways of scaling the independent variables (e.g., degree of massed practice).

This criterion classification approach to the Human Performance Data Base will be reported in:

Teichner, W.H. & Fleishman, E.A. Development of a Taxonomy of Human Performance: Evaluation of a Human Performance Classification Scheme for Generalizing Human Performance Data. Technical Report No. 8.

Information Retrieval Plans

A computerized coding and data retrieval system was developed and tried out for visual sensory detection, searching, and switching tasks. The work involved the retrieval techniques described on page 10 (see also Appendix F).

Although the taxonomic system used in this computerized data base was specially designed for the literature being surveyed, the indexing method, the procedures, and computer-compatible techniques seem to provide the kind of data base that will be needed in future years. Success in using this computerized approach is described in a technical report to be provided under the terms of a contract with the Navy. The report (currently in draft form) is entitled:

Teichner, W.H. & Krebs, M.J. Predicting Human Performance: I. Estimating the Probability of Visual Detection. (Draft of report to be submitted under Contract No. 0014-70-C-0125).

Evaluative Systems

Each of the various columns of Figure 2 are concerned with an evaluation of a provisional taxonomic approach. The ultimate evaluation in each case would involve the specific users of the information provided. This evaluation in terms of users had considerable influence on our design of plans for the study, as indicated by the organization of rows and columns in Figure 2.

Our conceptualization of user-oriented approaches to evaluation is an important product of the project. Some conceptual and procedural aspects of these approaches are reported in:

Miller, R. B. Development of a Taxonomy of Human Performance: A User-Oriented Approach to the Development of Task Taxonomies. Technical Report No. 6.

Preliminary notions regarding user-oriented evaluation systems also were contained in the Second Annual Technical Progress Report (Fleishman, Teichner, and Stephenson, 1970).

PROJECT REDIRECTION

The taxonomy project was undertaken as a basic research effort in response to long-range and pervasive problems in a variety of research and applied areas. The solution proposed was the development of ways to classify tasks which would improve predictions about factors affecting human performance in these tasks. Our effort thus represents one of the few attempts to find ways to bridge the gap between research on human performance and the applications of this research to the real world of personnel and human factors decisions.

The original proposal called for a five-year effort and the plan which evolved was depicted in Figure 1. Figure 2 indicates the provisional schedule under which we have been operating. During the middle of the third year, however, several reviews of the present project were made by project staff and by behavioral sciences representatives within the Department of Defense. These reviews were necessitated by problems of reduced research budgets within Department of Defense and by recent congressional amendments to defense appropriation bills requiring more immediate applied relevance of Department of Defense sponsored research. Representatives from various services and Department of Defense agencies concurred on the need and desirability of continuing the project, but some more direct coupling of the effort with on-going operational development seemed to be required.

In order to effect this coupling, responsibility for the project was transferred to the U. S. Army Behavior and Systems Research Laboratory (BESRL), under a new contract (No. DAHC-19-71-C-0004), entitled "A Taxonomic Base for Future Management Information and Decision Systems." This new contract calls for a transitional planning phase in which the project staff will select particular applications toward which the present language systems, methods

and procedures under development could be directed. This phase includes conferences with Department of Defense representatives concerned with such problem areas as planning future occupational job families and structures, developing new career ladders, training requirements, data banks, etc. This phase will also allow the completion of several reports in progress which describe the previous developmental work (see list of project reports).

ADDITIONAL PLANS

The redirection of the project naturally means that some of the effort described earlier may not be continued. The decisions as to which tasks will be retained will be made shortly and will depend on the outcome of planning conferences presently being conducted. In this section we provide brief mention of some plans already formulated by project staff, which may or may not fall within the scope of the new contract. These plans, not described elsewhere in this report, are an important product of our previous work and may be of interest to other investigators.

Ability-requirement approach

The ability-requirement approach, developed in the present project, utilizes rating scale techniques with careful attention to operational definitions, specification of descriptors, and anchoring of scales by task examples with known (empirically determined) scale values. An alternative approach worthy of tryout was the binary decision diagram for use in determining which abilities are involved in a task. The notion was suggested in the Second Annual Progress Report (Fleishman, Teichner, and Stephenson, 1970). The technique elaborates a similar approach already used by Meeker (1965, 1969) in order to assess the cognitive abilities required in certain test items (see Figure 3). We have extended the technique to observations of performance on jobs, experimental tasks, and simulators.

The advantage of the binary decision diagram techniques is that it would simplify the choices made by task observers, to go-no go decisions at various steps in the task analysis. Flow diagram models would need to be developed in detail, pretested, and revised.

Highly tentative diagrams developed for the perceptual and motor areas are shown in Figure 4a-4g. Pre-testing of portions of this model was carried out and certain revisions indicated, largely because of a

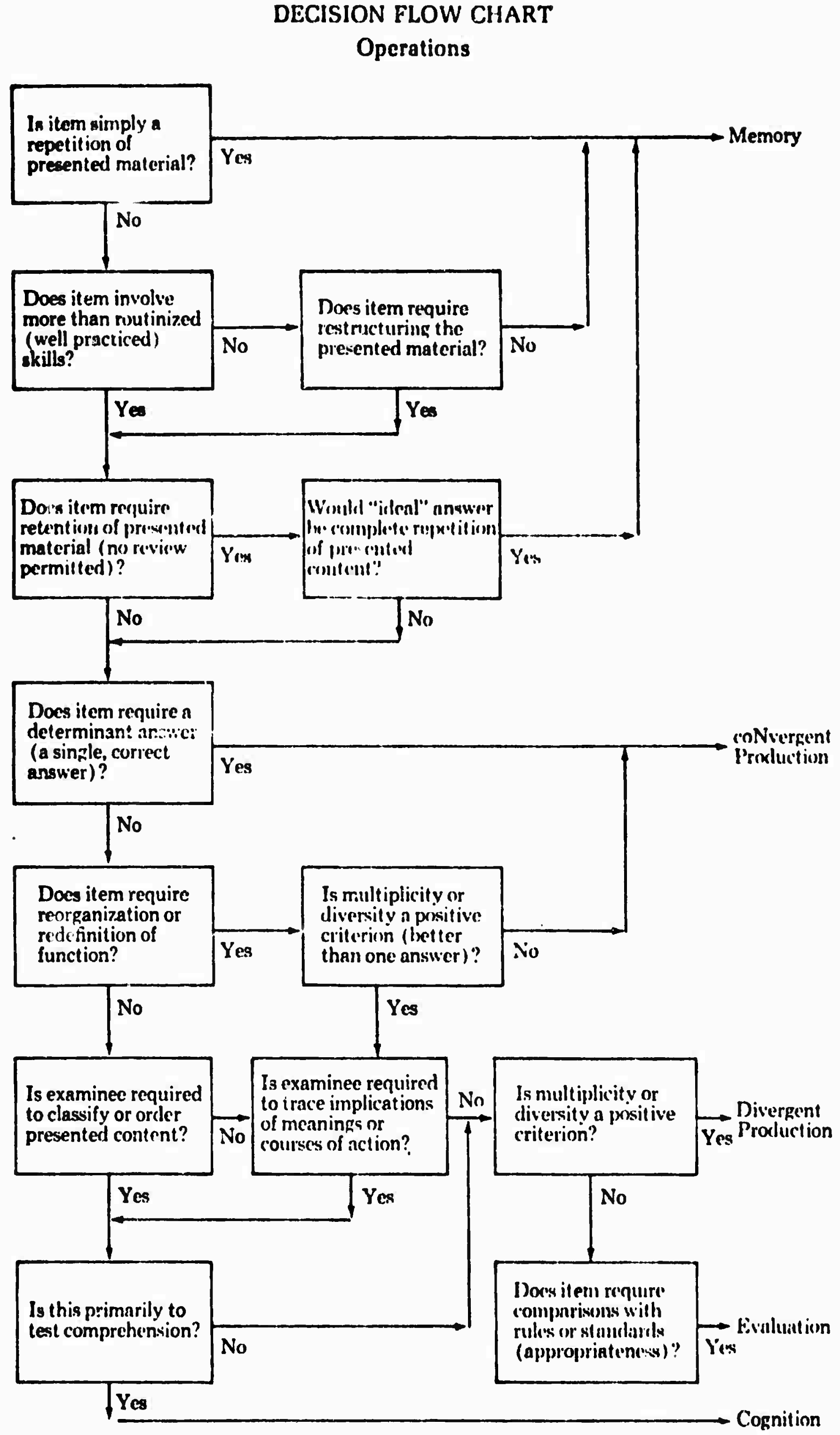


Figure 3. Example of binary decision diagram applied to decisions about cognitive ability requirements (Meeker, 1965, 1969)

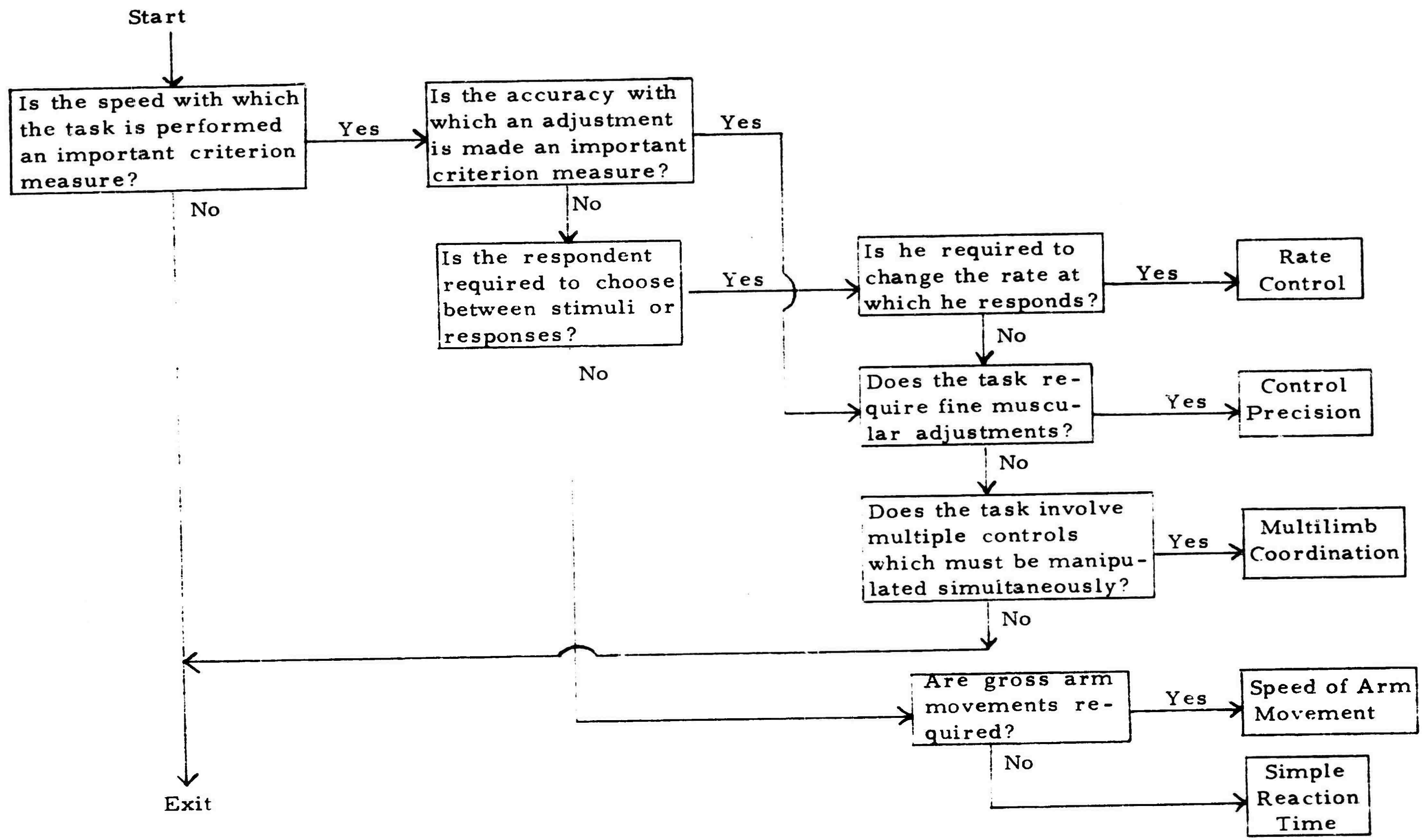


Fig. 4a. Tentative binary decision flow diagrams which can be used to make decisions about the relevance of selected perceptual-motor abilities.

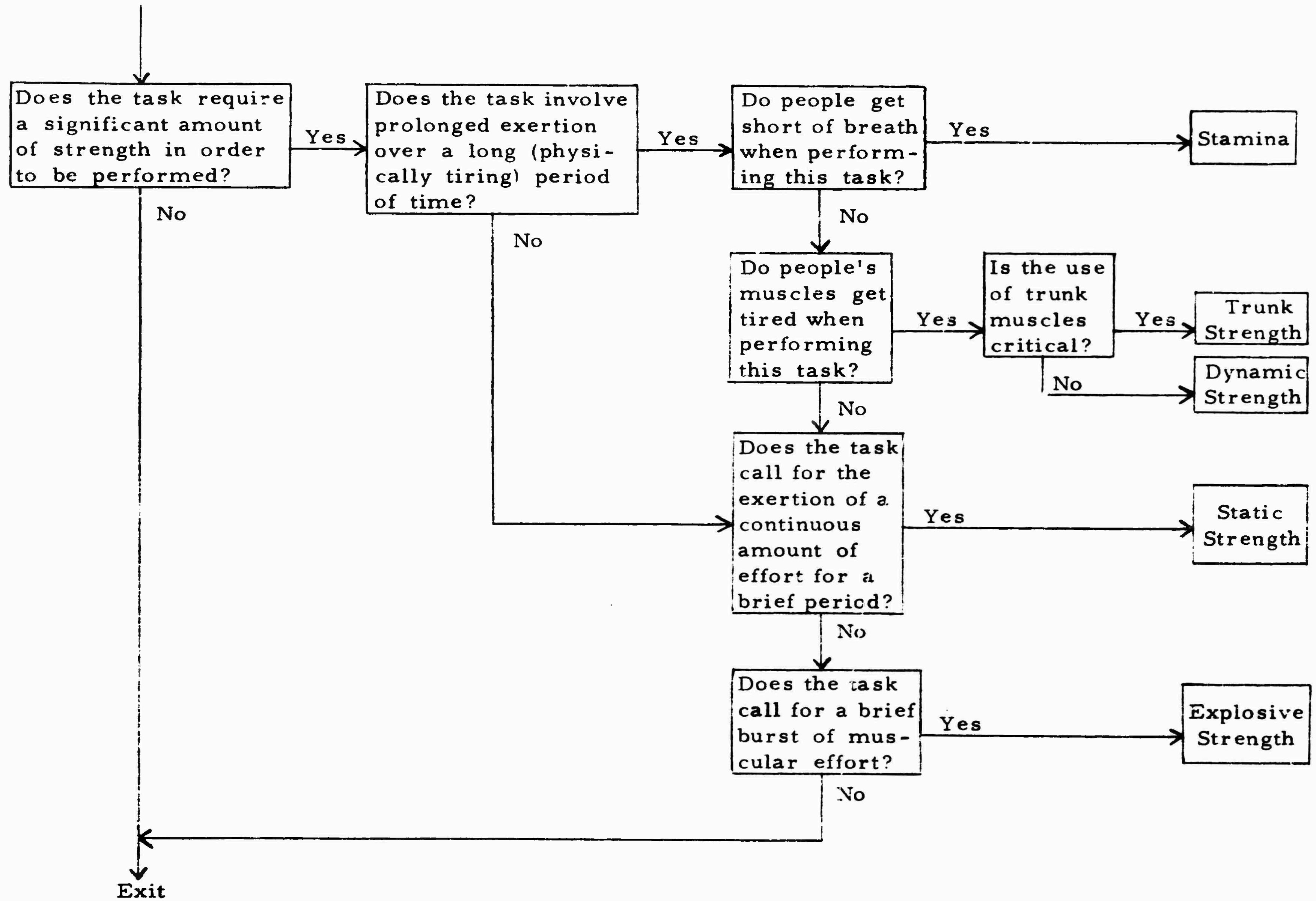


Fig. 4b. Tentative binary decision flow diagrams which can be used to make decisions about the relevance of abilities of strength and stamina.

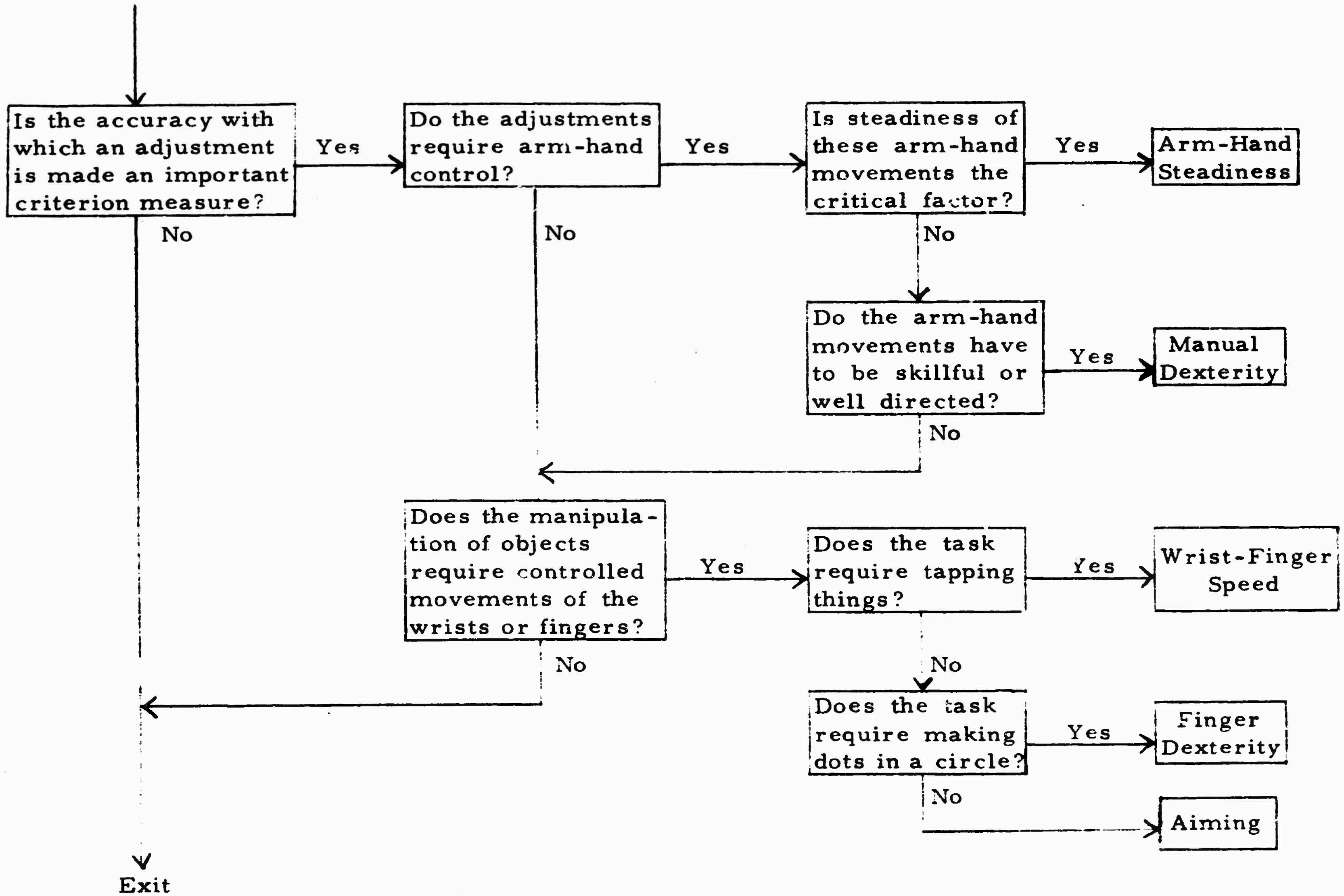


Fig. 4c. Tentative binary decision flow diagrams which can be used to make decisions about the relevance of fine manipulative abilities.

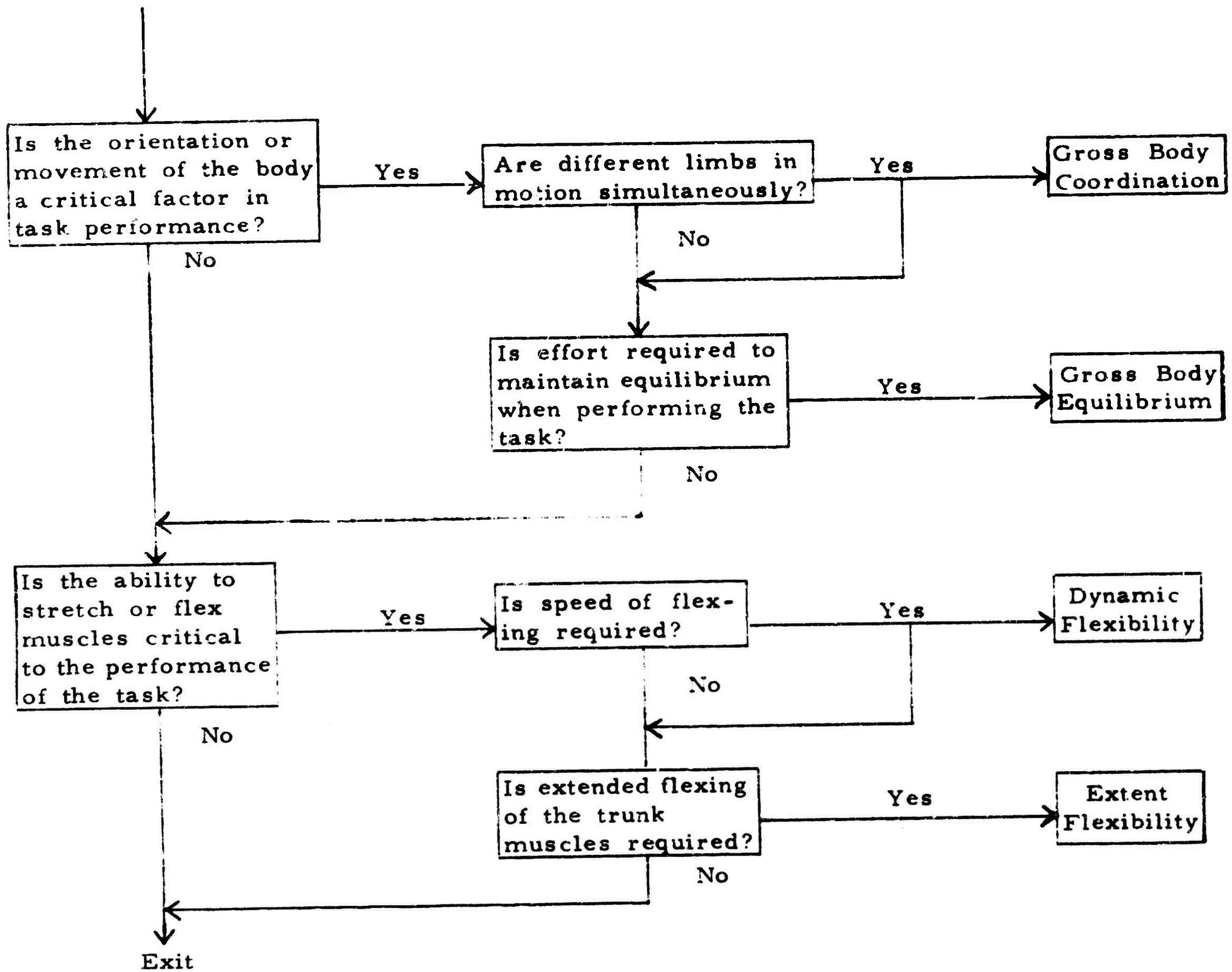


Fig. 4d. Tentative binary decision flow diagrams which can be used to make decisions about the relevance of gross physical proficiencies.

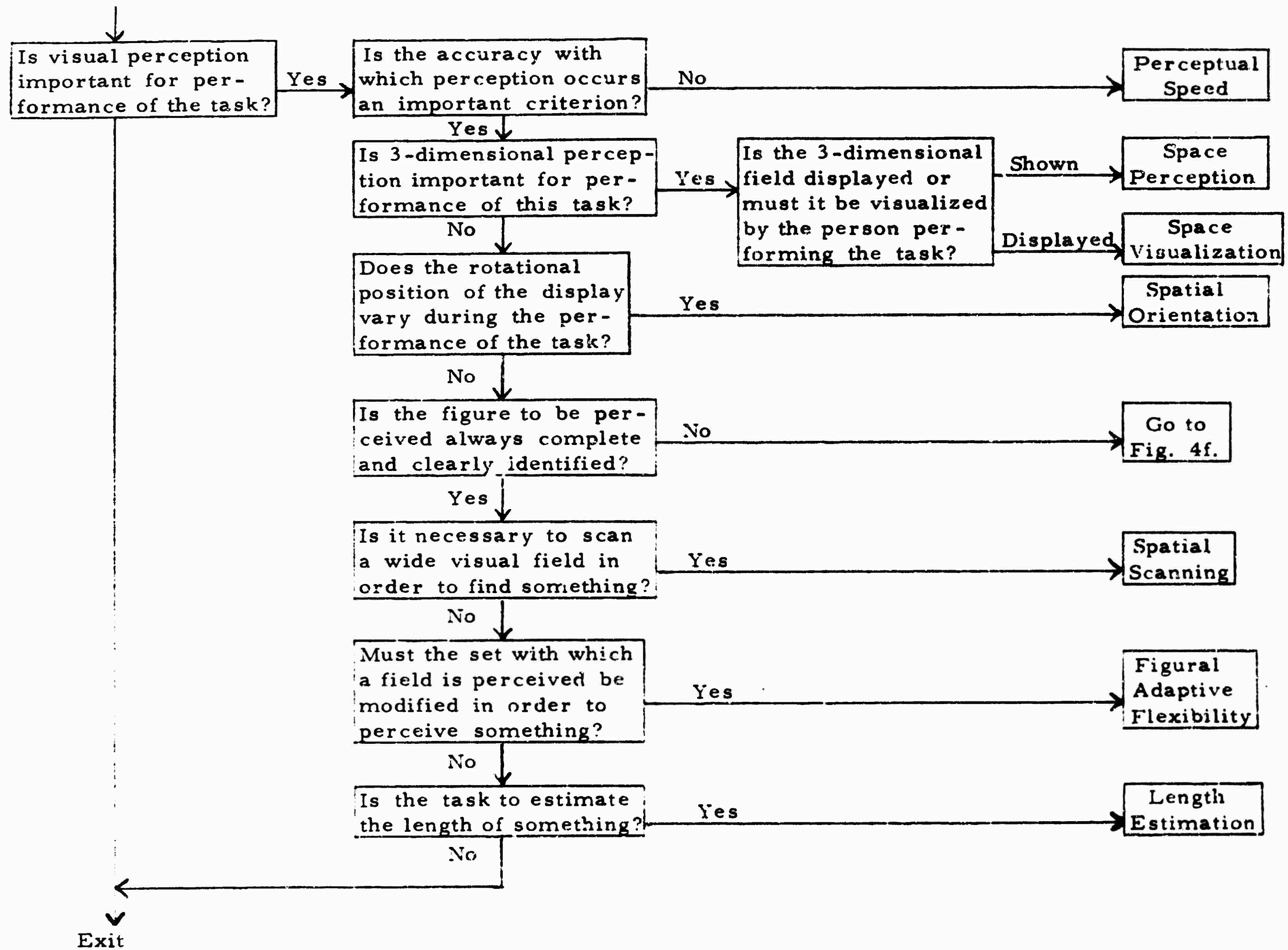


Fig. 4e. Tentative binary decision flow diagrams which can be used to make decisions about the relevance of perceptual (Group A) abilities.

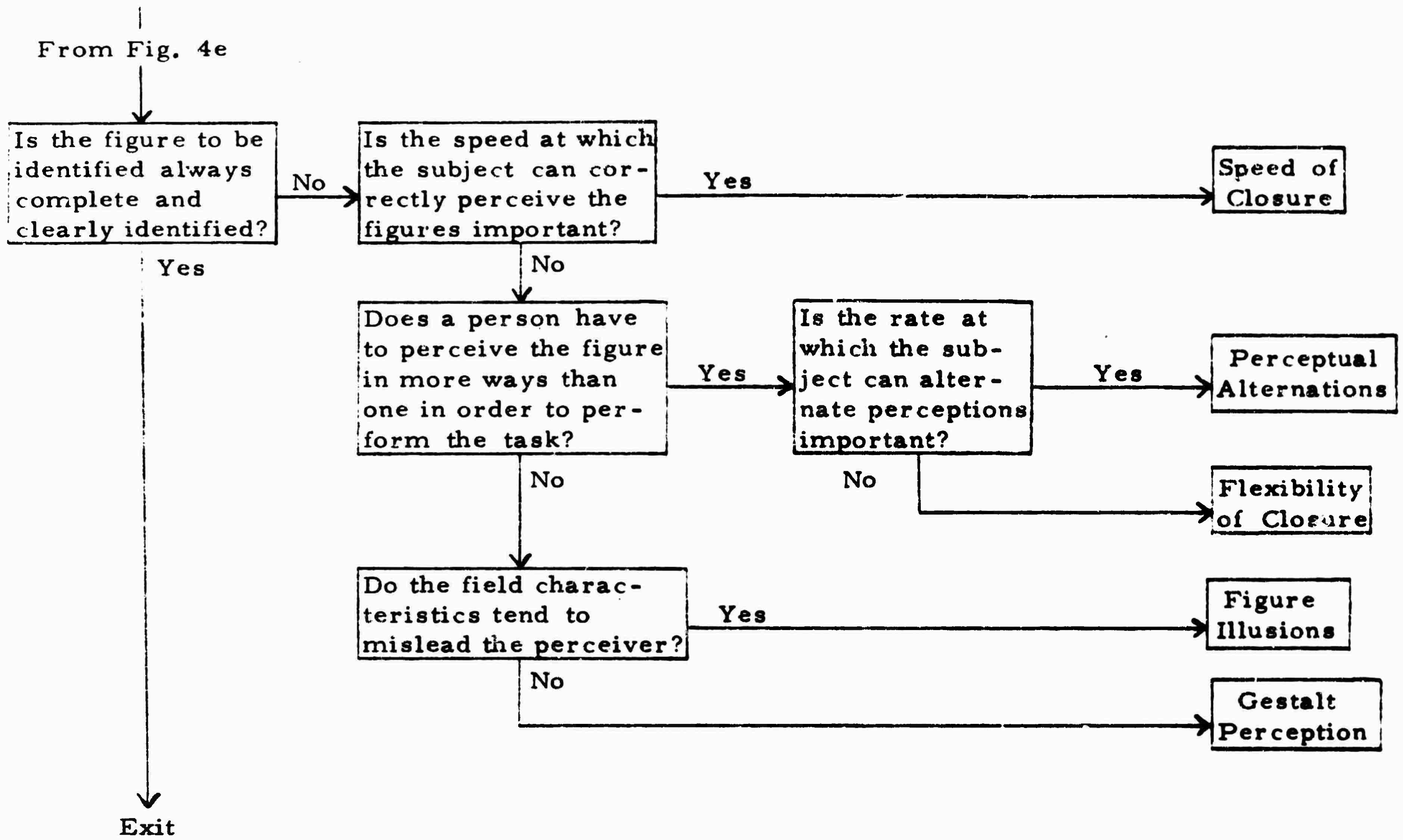


Fig. 4f. Tentative binary decision flow diagrams which can be used to make decisions about the relevance of perceptual (Group B) abilities.

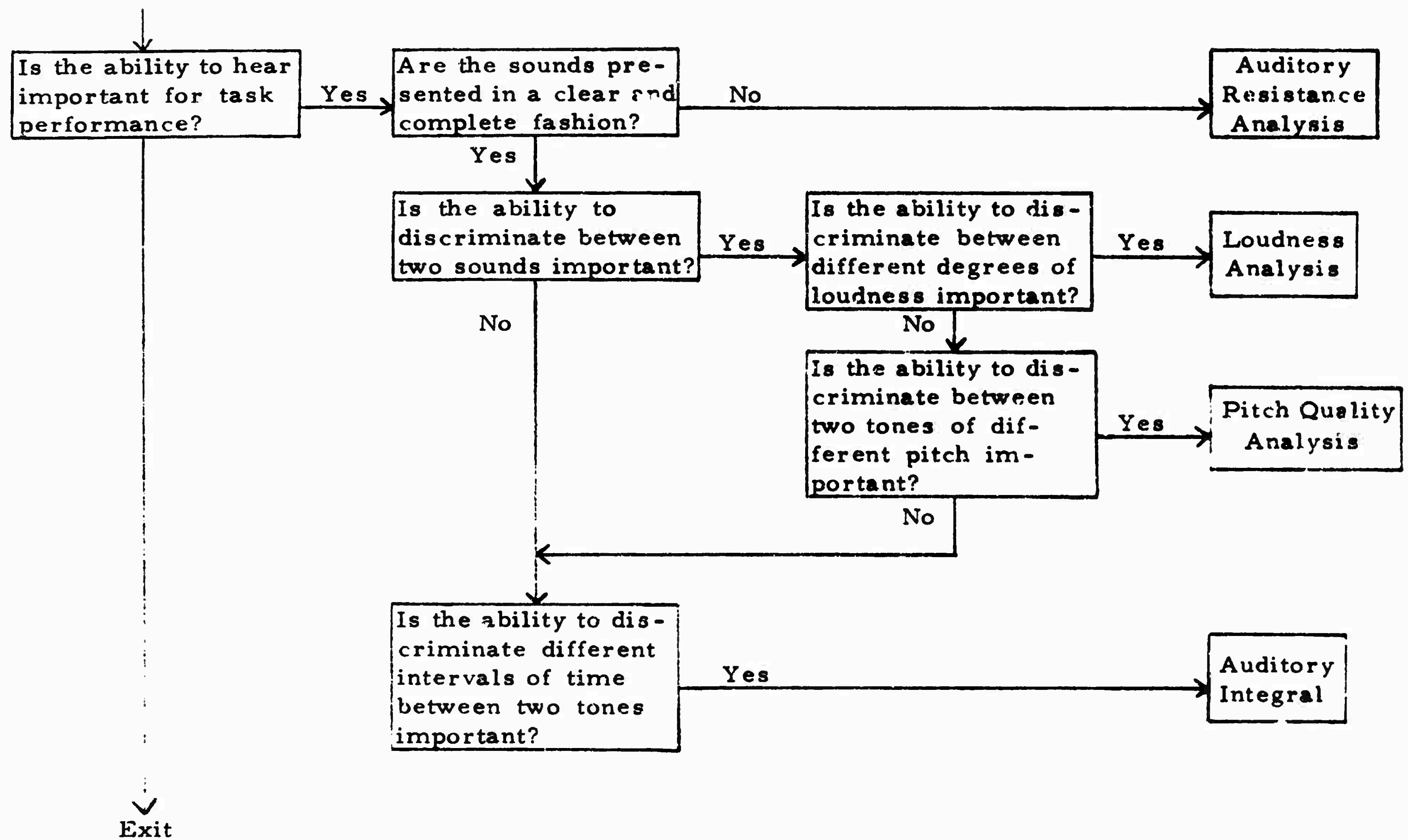


Fig. 4g. Tentative binary decision flow diagrams which can be used to make decisions about the relevance of auditory perceptual abilities.

problem of false positives (i.e., some abilities were designated as relevant for a task which did not have significant factors loadings with respect to that ability). There is apparently need to incorporate quantitative estimates of ability "levels" into the model before it can be developed further. The categories themselves and their definitions are all based on our analysis and adaptation of the empirical evidence on human abilities.

Task Characteristics Approach

Tentative plans formulated by those who developed the task characteristics approach are described in this section.

One of the more important classes of personnel decisions is that of determining the manpower needed to operate a new system. Personnel planning must take place many months in advance, and there is no acceptable way of determining how many people are needed. Other questions like this seem to require some way of predicting the productivity of personnel on the basis of the characteristics of the task.

The task characteristics approach would seem to lend itself to aspects to this kind of prediction problem. Such research could also be of considerable theoretical interest (see Figure 5). The task characteristics approach holds that P=f (O, E, T); i.e., that performance is a function of the operator, the task, and the environment. It would be possible to administer ability tests to the subjects (measuring operator characteristics), and have all the operators perform the same set of tasks. The tasks could then be rated with the task characteristic rating scales as well as the ability-requirement rating scales. Under such circumstances, one might ask questions such as the following. Which set of ratings would account for the most productivity variance? What is the interaction between task characteristics and ability-requirement characteristic ratings scales? What predictive efficiency results from using the task

Components of Variance	PERFORMANCE =	OPERATOR,	ENVIRONMENT,	TASK
Classes of Variables	Measures of performance	Operator Characteristics	Environmental Characteristics	Task Characteristics
Types of Variables	Total time on target % correct Probability of detection Etc.	I.Q. score Manual dexterity Control precision Abstract reasoning Measure of prior experience Etc.	Temperature Humidity Ambient illumination Ambient noise Etc.	Number of output units Stimulus predictability Etc.
Experimental Plan	Measure and record	Measure and record	Hold constant	Manipulate dimensional values

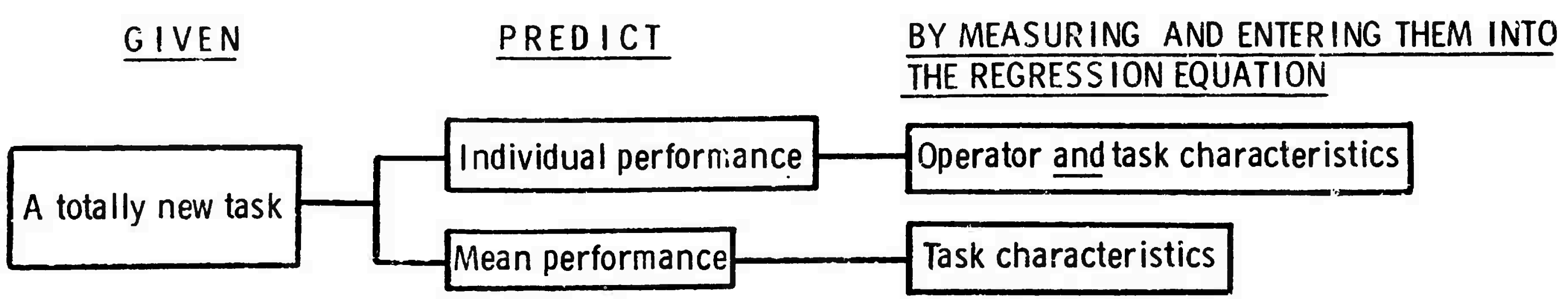


Figure 5. General plan for a predictive model based on the Task Characteristics approach.

characteristics alone, the ability tests alone, the ability ratings alone, or various combinations of these predictors jointly?

We already know from previous work (e.g., Fleishman, 1957, 1958, 1967a, Fleishman and Ellison, 1969) that changes in certain task characteristics produce systematic changes in abilities required in the task. For example, systematically varying the display-control relations of a task produced changes in the degree of perceptual speed and spatial orientation required to perform the task (Fleishman, 1957). The amount of involvement of these abilities (size of factor loading) differed with the degree of display rotation, and each ability showed its own functional relation with degree of display rotation. The experimental procedure involved administering measures of the abilities to subjects who performed the same complex task under different display-control conditions. As a result of the present project we have a much better conceptualization of critical task dimensions that can now be manipulated. It should be possible to build up a body of principles, using these methods, of allowing descriptions of tasks to be translated into ability requirements of individuals who could perform the task most effectively.

Systems Language Approach

The systems language approach described by Levine and Teichner (1970) must be subjected to experimental evaluation before it can be applied to operational tasks. This approach differs from the others in that it is a logical system which can stand or fall on the basis of research with very simple laboratory tasks. Basically the system language approach defines a task as an information transfer between a source and receiver in a system. All tasks are characterized as imposing constraints which are visualized as restrictions placed upon the random sampling of stimulus and response events. These constraints introduce redundancy into the information contained in the stimulus and response sets. We

postulate that tasks can be classified in terms of the effects of increasing amounts of redundance upon information transmission between the source and receiver.

The experimental evaluation of this approach will be a two-fold iterative procedure. On the one hand, a strictly theoretical activity will be carried forth by computer simulation of sampling constraints and the determination of the relationship between amount of redundance and transmitted information (H_t) under a variety of constraint combinations. On the other hand, a series of empirical investigations will be accomplished using tasks which allow the experimenter to manipulate input constraints and require the subject to provide output constraints. The influence of redundancy upon information transmission will be determined empirically and compared to the results of the computer simulation. If agreement is found we will have evidence for the viability of the system.

A series of experiments involving the control of selected constraints (e.g., rate and range of inputs) will be planned and conducted. Stimulus redundancy will be manipulated as the primary independent variable of interest. In general, subjects will be asked to perform a discrete information processing task while input constraints and redundancy are varied. Output constraints as determined by the response ensemble and/or as imposed by the subjects will be evaluated. Pattern classification, pattern identification, and signal detection tasks are the kind being considered for use. Studies of this type are capable of being conducted on the apparatus already developed on the project and described earlier in this report.

Information-Processing Approach

Under this project, Miller (1969) also has formulated plans for future research in connection with another version of a system language approach. Of particular interest are the "task strategies" used by "information processors" when they perform various kinds of tasks, since it is felt

that there are communalities of techniques which can be described in information-processing terms.

By "task strategy" is meant "some principle or policy for consistently selecting a given kind of alternative in a class of choice-making situations. Invariably, the strategy is a reference principle or concept for trading off one task variable against another in order to optimize a criterion variable or collection of criterion variables" (Miller, 1969). Examples of task strategies are:

(a) The sequencing of tests in troubleshooting which leads to the identification of the failing or replaceable part.

(b) The minimizing of changes in direction and acceleration when driving towards a given location.

(c) The minimizing of partial answers to be stored when programming steps for a computer.

(d) Packing a suitcase so that the number of folds are minimized.

(e) Reading ahead of where one's fingers are typing when typing a manuscript.

(f) Conserving energy by a long distance runner.

(g) Looking at the baseball more than once after it leaves the pitcher's hand.

(h) Giving differential weights to information inputs when a decision must be made.

Strategies on resource allocation which apply to the internal resources of the human effector mechanism are called behavior strategies. Strategies of resource allocation which apply to the external resources are called performance strategies.

Plans for research presuppose the training of several task description analysts in the use of this information-processing language as well as in the use of questions designed to identify the task strategies

employed by the personnel they observe. The reports and observed task strategies will then be translated into information processing terms, and a search for common principles across tasks will be made. Two of the principles which may be found are: (1) a cognitive tendency to optimize the amount of information to be processed in any given clump of time; (2) a tendency to develop buffers between input rates and output rates.

Data Base Effort

A data base study is needed to study the relationship between the various language systems developed by taxonomy project personnel. Teichner and Fleishman (Technical Report No. 8) have conducted a promising set of data base studies, in which specific functional relationships were found after they had categorized a number of studies from a taxonomy project data base according to a "task functions," criterion-measure classification scheme. It was not only possible to improve generalizations about the effects, overall, of a learning variable (e.g., massed versus distributed practice) through knowledges of the task's class, but it was possible to establish functional relationships between the level of the variables, and performance level on tasks within the classification. Other language systems developed in this project need to be applied to this same data base in order to compare the results from system to system and interrelate the various language systems.

This type of work has important implications for plans for management information and decision systems in future years. Comparisons of different sub-systems are often difficult to make because different applied decisions seem to benefit from different kinds of taxonomic languages. As noted earlier in this report, selection decisions seem to require an ability-requirement language; training decisions seem to benefit from a task-characteristics language; and equipment-design decisions seem to benefit from a systems language. Yet any future

personnel information decision systems must be able to translate between sub-systems and make trade-offs. Training, for example, is an alternative to equipment design in many circumstances. Yet--at least at the present time--the taxonomy project has not determined the translation between the language systems developed by project personnel.

User Oriented Evaluation System

The user-oriented approach to evaluation which we have developed (see Figure 2) requires an evaluation of each classification system in terms of its use for different purposes. There is a need to develop standardized sets of criterion data which can be used for this purpose in specific decision areas. We have suggested several possibilities of this type (see Table 1).

TABLE 1

Criterion Measures and Recommended Sources of Data

Study	Relevant Criterion Measure	Source of Data
Environmental Stress Prediction Study	Predict a zero, plus, minus matrix of results, in which zero means no effect, minus means a negative effect, and plus means a positive effect	Various sets of environmental stress studies in the AIR Performance Data Base (noise, temperature)
Correlation-Based Criterion Study	Predict the actual numerical values in selected factor analyses and validity studies	Large factor analyses (preferably with validity coefficients attached) to be selected from the literature
Equipment Design Criterion Study	Predict zero-plus-minus matrices of equipment design decisions (e. g., a decision to color code or subgroup dials, to increase or decrease the amount of redundancy in input information, etc.)	Descriptions of selected types of decisions must be solicited from appropriate government sources
Training Design Criterion Study	Predict matrices of training program design decisions (e. g., the effect of increases or decreases in the number of hours training, use of simulators, etc.)	Descriptions of selected types of decisions must be solicited from appropriate training agencies

SOME GENERAL COMMENTS ABOUT TAXONOMIC RESEARCH

Over a period of three years, we have developed a number of taxonomic systems (see Appendices A - F), each of which has the potential of organizing information about human performance. The systems are not comprehensive, they are in very uneven stages of development, and they need more work--but we consider their development to be an important accomplishment.

In addition to these specific products, we have also learned a great deal about the way to approach the problem of developing a taxonomy. Our notions on this more general subject are summarized in this final section of the report.

1. Think carefully about your purpose in developing a taxonomy before you start. Who is going to use the taxonomy after you develop it? Research scientists? Human engineers? Military managers? All of these? What outcomes are you trying to predict? Transfer of training? Effects of stress? Ability to perform a new task? For each outcome you select, do you want to specify which predictors you are interested in before you start? If not, are you willing to let the available data in the literature make those decisions for you? What is the size of the human performance unit you are trying to describe? Task elements? Tasks? Duties? Specific jobs? What decisions do you want the user to make with aid of your taxonomy?

2. Confine your attention to a specific subject matter areas in which you have expertise. Any human performance taxonomy worth using should have a theoretical base which helps us to understand the information as well as to organize it. Because of this requirement, we think it is best that people confine their attention to specific subject matter areas in which they have the capabilit to suggest changes in theory, techniques, and procedures.

3. __Begin by thinking about user-oriented evaluative systems.__ Taxonomic research must be closely tied to evaluative data which has clear-cut implications for user-satisfaction. Non-data oriented approaches to taxonomy run the risk of becoming more and more self-consistent at the same time that they become less and less relevant to the needs of the people who are supposed to make use of the taxonomies after they are developed. These users include other researchers as well as practitioners. A primary user, for example, is the experimental psychologist working in a substantive area, such as learning.

4. __Do not concern yourself with relationships to extraneous taxonomic systems at the outset.__ We are convinced that a general taxonomy will be developed eventually, and we also think that an improved computer technology will play an important part when this development takes place. Initially, however, we think that it is best if the taxonomic researcher confines his attention to those specific subject matter areas for which he has evaluative data.

5. __Use existing data to revise and improve the capability of the taxonomy to perform the function for which it was intended.__ We do not reject laboratory research on taxonomic systems. On the contrary, we think that such work (eventually) is essential for evaluating some of the purposes we would set forth for a taxonomy. On economic grounds, however, it is usually more practical to use a post-dictive approach rather than a predictive one, especially during the preliminary stages.

6. __Be alert to theoretical development as well as to procedure-standardization objectives.__ The need is not for a thesaurus of terms, but for a way of organizing information in terms of theoretically-based languages of descriptors. Standardization of procedures and techniques quickly becomes an important part of any development effort designed to produce such languages. In fact the two problems (inadequate theoretical description and inadequate standardization of tasks) are thoroughly confounded

in any set of studies which the taxonomic expert might wish to assemble into a data base.

7. Orient your long-range plans towards computerized retrieval of information. Books, documents, and journals are not likely to remain the basic source of information in future years. The data base of the future will probably be stored on a computer of some kind using the languages that are developed by the taxonomic researchers of today. Any future oriented taxonomy must recognize this prospective future and prepare for it.

8. Give your work on taxonomies a high priority. When we were screening the data base studies during the "quality filter phase" for possible use in our evaluations, we found that more than 60% of the studies in the journal literature could not be used because the characteristics of the task, the environment, and/or the operator were not stated with enough precision for us to categorize the work effectively. Part of this problem may be attributed to the inadequate standardization of research procedures, but part of the problem was clearly attributable to the lack of standardization in descriptive language. It would indeed be tragic if 60% of the studies in the literature had to be repeated--simply because the descriptive information needed to integrate them into a body of knowledge was not provided by those who conducted the study. Yet this situation does exist, and seems likely to continue until procedures have been standardized and the characteristics of task taxonomies have been determined.

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LIST OF PROJECT REPORTS

Completed

Wheaton, G. Development of a taxonomy of human performance: A review of classification systems relating to tasks and performance. Technical Report No. 1. Washington, D. C.: American Institutes for Research, December 1968.

Farina, A. J., Jr. Development of a taxonomy of human performance: A review of descriptive schemes for human task behavior. Technical Report No. 2. Washington, D. C.: American Institutes for Research, February 1969.

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Farina, A. J., Jr., & Wheaton, G. R. Classification in terms of task characteristics. Paper presented at the annual meeting of the American Psychological Association, September 1969.

Teichner, W.H. An information-theoretic approach to task classification. Paper presented at the annual meeting of the American Psychological Association, September 1969.

Korotkin, A.L., & Chambers, A.N. A human performance data base for evaluation of taxonomies. Paper presented at the annual meeting of the American Psychological Association, September 1969.

Papers in Preparation

Miller, R.B. Development of a taxonomy of human performance: A user-oriented approach to the development of task taxonomies. Technical Report No. 6.

Farina, A.J., Jr., & Wheaton, G.R. Development of a taxonomy of human performance: A task characteristics approach to performance prediction. Technical Report No. 7.

Teichner, W.H., & Fleishman, E.A. Development of a taxonomy of human performance: Evaluation of a human performance classification system for generalizing human learning data. Technical Report No. 8.

Levine, J.M. & Teichner, W.H. Development of a taxonomy of human performance: An information-theoretic approach. Technical Report No. 9.

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Miller, R.B. Development of a taxonomy of human performance: Design of a systems task vocabulary. Technical Report No. 11.

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Appendix A

Ability Requirement Approach

to Task Classification (Sample Scales)*

1. Verbal Comprehension
2. Verbal Expression
3. Ideational Fluency
4. Originality
5. Memorization
6. Problem Sensitivity
7. Mathematical Reasoning
8. Number Facility
9. Deductive Reasoning
10. Inductive Reasoning
11. Information Ordering
12. Category Flexibility
13. Spatial Orientation
14. Visualization
15. Speed of Closure
16. Flexibility of Closure
17. Selective Attention
18. Time Sharing
19. Perceptual Speed
20. Static Strength
21. Explosive Strength
22. Dynamic Strength
23. Stamina
24. Extent Flexibility
25. Dynamic Flexibility
26. Gross Body Equilibrium
27. Choice Reaction Time
28. Reaction Time
29. Speed of Limb Movement
30. Wrist-Finger Speed
31. Gross Body Coordination
32. Multilimb Coordination
33. Finger Dexterity
34. Manual Dexterity
35. Arm-Hand Steadiness
36. Rate Control
37. Control Precision

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*Theologus, Romashko, and Fleishman, 1970.
See next two pages for a sample rating scale taken from the Task Assessment Scales Manual.

1. VERBAL COMPREHENSION

This is the ability to understand language. It is concerned with the understanding of individual words as well as words as they appear in context; i. e., in sentences, grammatical patterns and idiomatic phrases. In terms of communication, this ability is limited to the receiver of information; it does not apply to the sender or communicator.

VERBAL COMPREHENSION DISTINGUISHED FROM OTHER ABILITIES:

Understanding individual words and words in context.	vs.	Ideational Fluency (3): Production of ideas relevant to a topic.
Characteristic of receiver of information.	vs.	Verbal Expression (2): Characteristic of sender of information.

1. VERBAL COMPREHENSION

Requires the understanding of complex, detailed information which contains [illegible]al words and phrases and involves fine distinctions in meaning among words.

Understand in entirety a mortgage contract for a new home.

Understand a newspaper article in the society section reporting on a recent party.

Understand a comic book.

Requires a basic knowledge of language necessary to understand simple communications.

Appendix B

Task Characteristics Approach to Task Classification

(Sample Scales)*

Sixteen rating scales have been selected for this rating task. Each task should be rated on all 16 scales. As you assigned a scale value to the task, write down the scale value on the line for that rating scale as listed below. There is space at the bottom for you to describe any problems you had in applying the scales to the task.

1. Number of output units_________
2. Duration for which an output unit is maintained_________
3. Number of elements per output unit_________
4. Work load_________
5. Precision of responses_________
6. Response rate_________
7. Degree of muscular effort involved_________
8. Simultaneity of responses_________
9. Number of procedural steps_________
10. Dependency of procedural steps_________
11. Variability of stimulus location_________
12. Stimulus or stimulus complex duration_________
13. Regularity of stimulus occurrence_________
14. Operator control of the stimulus_________
15. Operator control of the response_________
16. Rapidness of feedback_________

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*Farina and Wheaton, 1970. See next page for sample rating scale taken from the Task Characteristics Manual.

9. OPERATOR CONTROL OF THE RESPONSE (OCOR)

Given the occurrence of the stimulus, what degree of control does the operator have over when he must initiate his response.

Definitions		Examples
Full operator control - the operator is the sole determiner of when the response will be made.	7	• Playing a game of chess by yourself where you play both sides and there is no time limit for responding.
	6	
	5	
Partial operator control - the response must be made within a reasonable time after the stimulus occurs but the operator determines when within the interval the response will take place.	4	• The traffic light turns red when you are 500 yards from it; you have options as to when you will hit the brake.
	3	
	2	
No operator control - the operator must respond as soon as the stimulus occurs.	1	• Typical reaction time task. When the light comes on, push this button as fast as you can.

Appendix C

An Information-Theory Systems-Language Approach to Task Classification*
(Categories and Definitions)

The systems-language developed by Teichner and Levine consists of five categories of "constraints." These are:

1. Constraints on input due to restrictions placed on random sampling of stimuli from source.
2. Constraints on input prescribed by task.
3. Constraints imposed <u>on</u> the subject by the task requirements.
4. Constraints imposed by <u>S</u> due to performance limitations.
5. Constraints imposed on output by task requirements.

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*Teichner, 1970, and Levine and Teichner, 1970. See next page for examples of these constraints.

	Source	Input	Receiver
(Kinds of Constraints)	Constraints on input due to restrictions on random sampling of stimuli from source	Constraints on input prescribed by task	Constraints imposed <u>on</u> the subject by the task requirements
(Examples of Constraints)	Rules specifying: How stimulus population is sampled? Which stimuli are sampled?	Ensemble Size Presentation Rate Stimulus Range Sequential, Spatial, Conditional, etc. characteristics	Add inputs; Respond to every third input; Push spatially corresponding button, etc.
(Specific Example of Task) "Pattern Recognition"	(a) 8 x 8 matrix of lights (b) Pattern is any set of 8 lights such that only one light per column is lit	(a) Patterns come on at a rate of one every 10 seconds for a .5 second duration (b) Twenty different patterns used (c) No pattern can repeat until all are shown	(a) Respond only to those patterns which have four or more rows lit (b) Reproduce pattern by depressing spatially corresponding set of buttons (c) Use one hand and depress only one button at a time

Operation of Constraint Categories on Components of Communi

A

traints on input cribed by task	Constraints imposed on the subject by the task requirements	Constraints imposed by S due to performance limitations	Constraints impose on output by task requirements
Input	Receiver	Output	
mble Size entation Rate ulus Range ential, ial, itional, etc. charac-teristics	Add inputs; Respond to every third input; Push spatially corresponding button, etc.	Response Time: Encoding/Decoding Limitations; STM; LTM; etc.	Response Ensemble Characteristics
Patterns come on at a rate of one every 10 seconds for a .5 second duration - Twenty different patterns used No pattern can repeat until all are shown	(a) Respond only to those patterns which have four or more rows lit (b) Reproduce pattern by depressing spatially corresponding set of buttons (c) Use one hand and depress only one button at a time	(a) Response time (b) Short term memory (c) Other undefined	(a) 8 x 8 matrix of buttons

f Constraint Categories on Components of Communication Model

B

Appendix D

An Information-Processing Systems-Language Approach to Task Classification*

(Categories and Definitions)

1. Message - a collection of symbols sent as a meaningful statement.
2. Input Select - selecting what to pay attention to next.
3. Filter - straining out what doesn't matter.
4. Queue to Channel - lining up to get through the gate.
5. Is something there?
6. Search - looking for something.
7. Identify - what is it and what's its name?
8. Code - translating the same thing from one form to another.
9. Interpret - what does it mean?
10. Categorize - defining and naming a group of things.
11. Transmit - moving something from one place to another.
12. Store - keeping something intact for future use.
13. Short Term Storage (Buffer) - holding something temporarily.
14. Count - keep track of how many.
15. Compute - figuring out a logical/mathematical answer to defined problem.
16. Decide/Select - choose a response to fit the situation.
17. Plan - matching resources in time to expectations.
18. Test - is it what it should be?
19. Control - changing an action according to plan.
20. Edit - arranging/correcting things according to rules.
21. Display - showing something that makes sense.
22. Adapt/Learn - remembering new responses to a repeated situation.
23. Purge - getting rid of the dead stuff.
24. Reset - getting ready for some different action.

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*Miller, 1969. Note that the colloquial phrase for each term is intended as a mnemonic aid, not as a definition. See next two pages for a sample definition.

DETECT: Is something there?

Procedures and mechanisms for sensing the presence or absence of a cue or condition requiring that some form of action should be taken by the system.

Detection requires the discrimination of an action-stimulating cue from some background of stimulation.

What is detected may consist of normal work cues, or of exceptions (such as errors). The source of these cues may be inputs to the system, or feedback from the monitoring of outputs. The sensing function does not analyze or classify the cue.

Note: Detecting, as defined here, is confined to a sensing operation which excludes interpreting activities. In human terms, detecting results in sensing a stimulus to which attention will be paid. In many practical situations, however, detecting and identifying are a single process (see Identify).

Scanning and Detecting

Unless the sensor is a part of a fixed channel, it must scan segments of its environment so that the sensor is exposed to signals. The sensor is preset to respond to certain kinds of change or discontinuity in the field being scanned.

Principles

1. The response lag of the detecting device must be less than the cycle time of the stimulus to be detected.

2. The greater the contrast between the stimulus to be detected and its background, the greater the reliability of detection.

3. For given kinds of signal patterns to be detected, some scan patterns and frequencies are better than others.

4. In human behavior, what will be detected is related to "set" or pre-established tendencies to respond. More simply, we tend to notice what we expect to see, or what we are looking

for, or what we are attending to. A number of principles in addition to Item 2 influence human detection, as well as other sensing and perceptual behavior.

Comment

In digital processing activities detecting and identifying cannot be separated. But in analog activities a sensor may detect a pattern of frequencies representing a speaking voice, but not be able to identify it or its content.

Appendix E

A Criterion Measure Approach to Task Classification*
(Categories and Definitions)

The criterion measure language used by Teichner and Fleishman consists of five major categories. These were:

1. Searching
2. Switching
3. Coding
4. Tracking
5. Complex tasks

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*Teichner and Fleishman, 1971. See next page for definitions of these terms as they were used in classifying data base studies.

Appendix E

A Criterion Measure Approach to Task Classification

Searching: The exposure of a sensor to positionally different signal sources or to one source at different times. Searching is receptor orienting or signal seeking. It may be simple orienting as when the ears are positioned to enhance reception of a novel stimulus, or successive orienting also called scanning. Examples are monitoring, reconnaissance, target seeking. The descriptive measure that will be employed is the probability of detection.

Switching: A discrete action which changes the state of the next component in a system. Examples are turning anything on or off, go or no-go, or, in general, making a discrete, selective action involving categorical choices. In a system sense, switching should be described as the time between the initiation of the signal and the completion of the switching response. However, this time will depend critically on the characteristics of the switch that is used. Thus, movement time will be longer the longer the required switch movement, the greater the required torque, etc. Since these factors cannot be anticipated, they must be estimated from specific analysis of the system of interest. Aside from these factors, switching responses vary in the time from the initiation of the signal to the initiation of the response, that is, in reaction time. Therefore, the reaction time or latency is the descriptive measure that will be used to describe switching.

Coding: The naming or identifying of a detected signal. Simple coding involves the attachment of a name to characteristics of a stimulus such as color, pitch, direction of movement, position, etc. Group coding refers to the grouping of stimulus characteristics into a single classification such as silverware for knives, spoons, and forks, or "John" for a person, or "attack" for a battle procedure, etc. Successive coding implies a syntax or set of rules which is used to relate or transform names or codes. Examples are translating language and computing. The descriptive measure to be used is the percent of correctly coded responses or equivalent, such as the percent of error.

Tracking:	Alignment of a response with a changing input. Tracking may be pursuit or compensatory as conventionally used. Examples of tracking are steering, aiming, walking, tuning. The measure to be used will be the percentage decrement in time on target. The use of a relative measure is dictated by the fact, as with switching, that actual time on target will depend on target width, etc., and, therefore, must be determined uniquely.
Complex Tasks:	Many tasks can be thought of as combinations of the above carried out either simultaneously or in succession. For example, <u>problem solving</u> may be thought of as successive searching plus coding, plus switching; <u>reading</u> may be thought of as successive coding plus tracking; <u>handwriting</u> may be thought of as tracking plus successive coding.

Appendix F. Examples of Data Base Information Categories Extracted from the Literature on Visual Detection Categories

Number Code	Word Code	Explanation	Applicable To* or**
01	Reference	Author, title, source, data, volume pages	All tasks
02	Experimental Method	Psychophysical method used to present stimuli, e.g., method of constant stimuli.	Sensory detection
03	Subject or Experimenter Control	Did the subject control the presentation of the stimulus or did the experimenter either manually or automatically?	Sensory detection
04	Subjects	Number of subjects used per group or condition whose data were included in the analysis, and their age, sex, and occupation if given.	All tasks
05	Group vs. Individual Sessions	Were subjects run one-at-a-time or as a group?	Sensory Detection
06	Time per session	For how long a time was the subject used at one appointment? Were there rest periods?	All tasks
07	Number of sessions	How many experimental sittings with what temporal distribution?	All tasks

*Indicates that the information is considered important for the task, but was not included because it was not reported in the literature.

**Indicates that the information is considered important for the task, but was not included because of a deliberate, (temporary) reduction in the scope of this effort.

Number Code	Word Code	Explanation	Applicable To
08	Number of stimulus events displayed per session	How many different displays were presented? A display might or might not contain a target, but it is always a unique event to which a response can be made. Of the displays, how many contained target(s)?	All tasks
09	Method of response	Verbal response, manually operated switch, etc.	Switching
10	Practice	How much practice was provided before critical measures were taken? How experienced was the subject at the task? How much practice under environmental stressor?	All tasks
11	Wavelength	Wavelength property of signal light.	Sensory detection Switching (RT_s)
12	Monocular or Binocular	Were two eyes or one used by the subject?	All tasks
13	Dark adaptation	How much time was allowed in the dark for retinal dark adaptation before presentation of the stimulus?	All tasks
14	Target type	Light flash, digit, letter, geometric form, color, lines, gaps	All tasks
15	Location of stimulus or retinal position	Location in space with the subject as reference or angular distance from fovea (viewing angle)	Sensory detection Searching** Switching (RT_s)

Number Code	Word Code	Explanation	Applicable To
16	Target size	Physical size (diameter or area)	All tasks
17	Viewing distance	Distance of target from subject	All tasks
18	Visual size	Retinal size in angular measure	All tasks
19	Intensive properties of target	Intensity, luminance, etc.	All tasks
20	Intensive properties of field and/or background	Field luminance; background luminance	All tasks
21	Contrast	Let T be the Target, B the background, and C the contrast. When T B, $C = \frac{T-B}{B}$ and has a limit =00, when T B, $C = \frac{B-T}{B}$ and has a limit = 1.00.	All tasks
22	Duration of target	Target exposure time	All tasks
23	Threshold Value	Definition of threshold, e.g., 50% detection, or 50% corrected for guessing, or 60% detection, etc.	Sensory detection
24	Size of search field	Area within which targets could appear	Searching
25	Spatial distribution of targets	What constraints on target location within the field?	Searching Switching (RT, CRT)

Number Code	Word Code	Explanation	Applicable To
26	Probability of occurrence of targets in a given part of the field	What proportion of the number of targets presented fell in that part of the field?	Searching Switching (RT, CRT)
27	Number of different possible signals	Number of alternative targets in the source, i.e., target possibilities defined by instruction to the subject.	Searching Switching (CRT)
28	Information Content	Amount of stimulus information in bits.	Searching** Switching (CRT)
29	Probability of occurrence	Proportion of times a signal occurs.	Searching Switching (CRT)
30	Warning Signal	A signal presented prior to test signal; the nature of the warning signal is indicated.	All tasks
31	Foreperiod	Time between offset of warning signal and onset of test signal	All tasks
32	Presentation rate or inter-signal interval (ISI)	Number of signals per unit time; time between successive onsets of warning signals, if used, or of test signals if warning signals not used;	All tasks
33	Intertrial interval (ITI)	Time from end of response to onset of the next warning (or test) signal	All tasks

Number Code	Word Code	Explanation	Applicable To
34	$F(D_s)$	Sensory probability of detection of the presented signal	Searching Switching (RT_s)
35	Number of targets displayed	Number of targets presented simultaneously	Searching Switching (CRT)
36	Constancy of target definition	Were the events designated as targets the same throughout a session, or was the subject told to respond to a different target(s) as correct before each trial or trial set?	Searching Switching (CRT)
37	Position uncertainty	If each target occurs in a unique location, then a non-positional target code is confounded with location. In such cases, location is redundant and has no uncertainty; if there is no correlation between location and target code, then there is a location or position uncertainty.	Searching Switching (RT, CRT)
38	Time uncertainty	If the ISI and the ITI are constant or if the foreperiod is constant, there is no time uncertainty about the occurrence of the test signal assuming a well-practiced subject. Otherwise uncertainty about when the signal occurs is assumed.	Searching Switching (RT_s, RT*, CRT) Sensory detection*
39	Number uncertainty	When the number of targets presented simultaneously is variable from trial (or trial set) to trial and the subject does not know what the number on any coming trial will be, number (of targets) uncertainty is assumed.	Searching Switching (CRT)

Number Code	Word Code	Explanation	Applicable To
40	Visual noise	May take the form of optical distortion, interspersed or overlaid lines, shapes, dots, etc. or may be irrelevant or non-target digits, letters, colors, geometric forms, etc., i.e., irrelevant, but coded stimulus events. Parameters of noise are not reported. Only noise occurring simultaneously with targets are reported.	Sensory Detection* Searching Switching
41	Duration of vigil	In watchkeeping or monitoring, the length of time of a session of continuous monitoring	Searching Switching (RT, CRT)
42	Acclimatization	History of pre-exposure of subjects to the environmental variable(s).	All tasks
43	Environmental variables	Environmental conditions and how achieved, e.g., altitude chamber, compressed gas sources, etc.	All tasks
44	Environmental exposure	Duration of exposure prior to and during environmental conditions. The time relation to the performance measure is indicated.	All tasks
45	Recovery	Duration of the period between or following environmental exposure(s)	All tasks
46	Exposure Frequency	Number of environmental exposures and recoveries during test session	All tasks
47	Number of exposure sessions	Number of exposure sessions on which reported data are based	All tasks

Number Code	Word Code	Explanation	Applicable To
48	Physiological measures	Major physiological measures reported and when taken.	All tasks
49	Biochemical measures	Major biochemical measures reported and when taken.	All tasks
50-58	Not used--available for later use		
59	Additional variables	Independent variables whose effects are reported in the paper, but which are not cited in the data base.	All tasks
60	General statement	Statement of the general purpose and conclusions of the author and special comments of importance to use of the data.	All tasks

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13. ABSTRACT

The purpose of the AIR taxonomy project is to develop and evaluate systems for describing and classifying tasks which can improve generalization of research results about human performance and to develop a common language for communicating between researchers and individuals who need to apply research to personnel problems. During two previous project years, three different taxonomic systems were developed, each of which seemed to have maximum relevance for a different type of application: the ability-requirement approach; the task characteristics approach; and a third approach based on information-theory.

During the third project year, two of the three provisional approaches were subjected to user-oriented evaluations. The ability-requirement and task characteristics approaches were used to post-dict mean values of performance measures and relevant factor loadings for a variety of tasks. Work was also initiated on the design of binary decision flow diagrams of the type that will simplify decisions about ability requirements so that decisions can be made by relatively untrained personnel. The information-theory approach was revised and reformulated as a more general systems-language approach; a specially designed experimental apparatus was built for its evaluation. Also, as a separate effort, a new "information processing" systems language was developed which seemed to be more readily adaptable to the description of complex tasks. Finally some evaluation was made of a criterion measure classification scheme.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Progress was made toward the development of computer-compatible information retrieval procedures developed to allow interested users to retrieve data according to the task descriptive system of interest. These procedures were applied to several portions of the Human Performance Data Base, previously assembled, with promising results. KEY WORDS: Ability requirements Task characteristics Systems language Information theory Human abilities Human performance Task taxonomy Information retrieval systems Human factors Data base Task assessment scales						